ACOUSTIC DUMPER FOR EXHAUST SYSTEM

Cross Reference to Related Application

This application claims benefit of priority under 35USC §119 to Japanese Patent Applications No. 2002-323065, filed on November 6, 2002 and No. 2002-324128, filed on November 7, 2002, the entire contents of which are incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an exhaust system to discharge exhaust produced in an engine of, for example, a vehicle or a compressor to the atmosphere and reduce noise caused by the exhaust.

2. Description of Related Art

Figure 1 shows an example of an exhaust system. The exhaust system includes exhaust tubes 1, a cast exhaust manifold 2 to collect exhaust from cylinders of an engine and send the collected exhaust to an adjacent one of the exhaust tubes 1, a catalytic converter 3 to convert a toxic substance such as CO, HC, and NOX contained in the exhaust into a harmless substance such as CO_2, H_2O, and NO_2 through catalytic reaction, and a premuffler 4 and rear muffler 5 to muffle noise caused by the exhaust. These components 2, 3, 4, and 5 are connected to each other through the exhaust tubes 1.

A flexible tube 6 is arranged between the exhaust tube 1 connected to the cast exhaust manifold 2 and the exhaust tube 1 connected to the catalytic converter 3, to flexibly connect the manifold 2 and converter 3 to each other.

In recent years, exhaust systems have tended to increase the diameters of exhaust tubes to reduce back pressure, or increase the volumes of premufflers and rear mufflers to improve a muffling effect. This tendency has resulted in increasing the cross-sectional areas of the mufflers.

Increasing the diameters of the exhaust tubes 1 may decrease a pressure loss and hardly attenuate pulsating pressure produced from the engine. The pulsating pressure sometimes changes into a shock wave. Namely, the pulsation easily results in emitting noise from a part of the exhaust system.

Enlarging the premuffler 4 and rear muffler 5 to increase muffling effect must

encounter limits related to a vehicle layout. To avoid the limits, the mufflers 4 and 5 may be enlarged with the use of flat cross-sectional shapes having large-curvature surfaces. Such large-curvature surfaces deteriorate the rigidity of the mufflers, to easily emit noise from the surfaces of the mufflers. The rear muffler 5 is usually larger than the premuffler 4, and therefore, it emits larger noise.

To reduce such noise, there are some recently disclosed techniques. For example, Japanese Unexamined Patent Application Publication No. 2002-21594 discloses a technique of changing the rigidity of a muffler to improve muffling efficiency, and Japanese Unexamined Patent Application Publication No. 9-49415 discloses a technique of filling a premuffler with noise absorbing material to improve the muffling effect of an exhaust system as a whole.

SUMMARY OF THE INVENTION

Muffling levels achieved by the disclosure 2002-21594 are variable depending on exhaust systems, and therefore, the disclosure is inapplicable to standardizing mufflers. Namely, the disclosure must properly set the rigidity of a rear muffler for a given exhaust system, to increase the cost of the exhaust system. The disclosure involves such an unsolved problem.

The disclosure 9-49415 uses a large quantity of noise absorbing material which increases the cost of the exhaust system. In addition, the noise absorbing material may scatter to deteriorate the muffling effect of the exhaust system and cause environmental problems. This disclosure involves such an unsolved problem.

The noise absorbing material absorbs condensed water and sticks to the exhaust system to deteriorate the muffling effect thereof. In addition, the noise absorbing material is difficult to recycle and poses a demerit against such recent social trends. It is preferable, therefore, not to use the noise absorbing material if possible.

To solve these problems, the present invention provides an exhaust system that is manufacturable at low cost and is capable of effectively reducing noise emission.

A first aspect of the present invention provides an acoustic damper structure including a tubular member configured to discharge exhaust from an engine or a compressor and attenuate acoustic energy of a first frequency band and a resonator set configured to attenuate acoustic energy of a second frequency band, which is different from the first frequency band, and modulate the first frequency band.

Based on the acoustic damper structure of the first aspect, a second aspect of the

present invention provides the resonator set with at least two resonators. Each of the resonators has an open first end opening to an inner face of the tubular member and a closed second end. The resonators have different lengths.

Based on the acoustic damper structure of the first aspect, a third aspect of the present invention provides the resonator set with at least one resonator. The resonator has an open first end opening to an inner face of the tubular member and a closed second end. The closed second end includes a plane that is not in parallel with the plane of the open first end.

Based on the acoustic damper structure of the first aspect, a fourth aspect of the present invention provides the resonator set with at least one resonator. Each end of the resonator is open to an inner face of the tubular member.

Based on the acoustic damper structure of any one of the first to fourth aspects, a fifth aspect of the present invention arranges the resonator set at an exhaust upstream side in a muffler connected to an end of the tubular member.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a general view schematically showing an exhaust system according to a related art;

Fig. 2 is a general view schematically showing an exhaust system employing an exhaust chamber according to a first embodiment of the present invention;

Fig. 3A is a sectional view showing the exhaust chamber according to the first embodiment;

Fig. 3B is a sectional view taken along a line IIIB-IIIB of Fig. 3A;

Fig. 4 is a graph showing a frequency analysis of muffler vibration acceleration;

Fig. 5 is a graph showing a frequency analysis of emitted noise;

Fig. 6 is a graph showing changes in linear attenuation center frequencies relative to noise reducer lengths;

Fig. 7 is a graph showing an influence of the diameter of a noise reducer on muffling effect;

Fig. 8 is a graph showing emitted noise characteristics relative to pulsator revolution speeds and exhaust chamber arranging positions;

Figs. 9A-9C are graphs each showing emitted noise characteristics relative to frequencies and exhaust chamber arranging positions;

Fig. 10 is a graph showing the emitted noise reducing effect of an exhaust chamber;

Fig. 11 is a graph showing a relationship between emitted noise levels and frequencies;

Fig. 12A is a view showing an exhaust chamber according to a modification of the first embodiment of the present invention;

Fig. 12B is a sectional view taken along a line XIIB-XIIB of Fig. 12A;

Fig. 13A is a view showing an exhaust chamber according to a second embodiment of the present invention;

Fig. 13B is a sectional view taken along a line XIIIB-XIIIB of Fig. 13A;

Fig. 14 is a sectional view showing an exhaust chamber according to a third embodiment of the present invention;

Fig. 15 is a sectional view showing an exhaust chamber according to a modification of the third embodiment of the present invention;

Fig. 16 is a general view schematically showing an exhaust system employing an exhaust chamber according to a fourth embodiment of the present invention;

Fig. 17A is a view showing the exhaust chamber according to the fourth embodiment of the present invention;

Fig. 17B is a sectional view taken along a line XVIIB-XVIIB of Fig. 17A;

Fig. 18A is a view showing an exhaust chamber according to an alteration of the fourth embodiment of the present invention;

Fig. 18B is a sectional view taken along a line XVIIIB-XVIIIB of Fig. 18A;

Fig. 19A is a view showing an exhaust chamber according to a first modification of the fourth embodiment of the present invention;

Fig. 19B is a sectional view taken along a line XIXB-XIXB of Fig. 19A;

Fig. 20A is a view showing an exhaust chamber according to an alteration of the first modification of the fourth embodiment of the present invention;

Fig. 20B is a sectional view taken along a line XXB-XXB of Fig. 20A;

Fig. 21 is a view showing an exhaust chamber according to a second modification of the fourth embodiment of the present invention;

Fig. 22 is a view showing an exhaust chamber according to an alteration of the second modification of the fourth embodiment of the present invention;

Fig. 23 is a view showing an exhaust chamber according to a third modification of the

fourth embodiment of the present invention; and

Fig. 24 is a view showing an exhaust chamber according to an alteration of the third modification of the fourth embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Various embodiments of the present invention will be described in detail with reference to the accompanying drawings.

Figures 2, 3A, and 3B show an exhaust system according to a first embodiment of the present invention, in which Fig. 2 is a general view schematically showing the exhaust system, Fig. 3A is a front view showing an exhaust chamber of the exhaust system, and Fig. 3B is a sectional view taken along a line IIIB-IIIB of Fig. 3A. In Fig. 2, parts corresponding to those of Fig. 1 are represented with like reference numerals. In Fig. 2, the exhaust chamber 10 according to the first embodiment of the present invention is arranged in a rear part (close to a rear muffler 5) of an exhaust tube 1. The exhaust tube 1 is a tubular member connecting a premuffler 4 to the rear muffler 5 in the exhaust system.

In Figs. 3A and 3B, the exhaust chamber 10 has noise reducers 12A and 12B protruding from an outer circumferential face 1a of the exhaust tube (tubular member) 1. The heights of the noise reducers 12A and 12B from the outer circumferential face 1a are different from each other by a predetermined value. The noise reducers 12A and 12B are resonators having closed top end faces 12Aa and 12Ba and open ends 12Ab and 12Bb, respectively.

In a case where the top faces 12Aa and 12Ba of the noise reducers 12A and 12B are substantially in parallel with the outer circumferential face 1a of the exhaust tube 1, the number of the noise reducers is, for example, two with the distances from the outer circumferential face 1a to the top faces 12Aa and 12Ba of the noise reducers 12A and 12B being different from each other by a predetermined value. As will be explained later, the difference between the protruding heights of the noise reducers 12A and 12B and the cross-sectional areas (orthogonal to an axis x) of the noise reducers 12A and 12B are important factors according to the present invention. The positions of the protrusions of the noise reducers 12A and 12B may be anywhere on the exhaust tube 1 except on the same circumference line around the exhaust tube 1. As will easily be understood, it is preferable to protrude the noise reducers 12A and 12B in the same direction to make the exhaust chamber 10 compact.

The exhaust chamber 10 with such a structure is shaped to reduce frequency levels

that generate noise from the exhaust chamber 10 itself. The exhaust chamber 10 is manufacturable by forming two sheet materials into proper shapes by, for example, pressing and by joining the shaped materials together by, for example, butt welding or caulking.

To reduce nose generated in the rear muffler 5, a measure must be taken at a stage in front of the rear muffler 5. Namely, it is necessary to suppress frequency levels passing through the exhaust tube 1 and causing noise in the rear muffler 5.

Figure 4 shows a relationship between muffler vibration acceleration levels and noise frequencies, and Fig. 5 shows a relationship between noise levels and noise frequencies. As is apparent in Figs. 4 and 5, particularly problematic noise components are high-frequency components in the range of 500 Hz to 3000 Hz (as depicted by Δf). The noise levels of these high-frequency components are particularly high.

This tendency more or less appears in substantially every exhaust system, and therefore, the present inventors have paid attention to noise consisting of the frequency components in the range of 500 Hz to 3000 Hz. The inventors considered that noise emitted from a rear muffler of substantially any exhaust system is suppressible by providing an exhaust system with a resonator structure having a resonance characteristic that is different from the resonance characteristic of the exhaust system itself.

The present inventors have employed a linear attenuation center frequency as an index representative of a level reducing characteristic. Figure 6 shows an example of measurement of the dependence of a linear attenuation frequency on the longitudinal lengths of the noise reducers 12A and 12B (hereinafter referred to as noise reducer lengths). According to the analysis result shown in Fig. 6, frequency levels that cause noise in the range of 500 Hz to 3000 Hz can be reduced by setting the protrusion heights (shortest distances from the outer circumferential face 1a of the exhaust tube 1 to the top faces 12Aa and 12Ba) of the noise reducers 12A and 12B to values in the range of about 30 mm to 150 mm.

The exhaust chamber 10 according to the embodiment of the present invention makes compression waves in a predetermined frequency band resonate or interfere with one another to expedite the dissipation of acoustic energy of the compression waves and attenuate the vibration components thereof. The exhaust system has resonant elements that have the frequency characteristic (first frequency band) of Figs. 4 and 5 to attenuate acoustic energy. The exhaust chamber 10 according to the embodiment is a resonator set configured to provide a frequency characteristic (second frequency band) that is different from the frequency characteristic of the

exhaust system itself. Accordingly, when added to the exhaust system, the exhaust chamber 10 of the embodiment serves as an acoustic damper to modulate and correct the frequency characteristic of the exhaust system itself.

Figure 7 shows the attenuation characteristics of the noise reducers 12A and 12B provided with cylindrical shapes having three different diameters. Changing the diameters of the noise reducers changes a frequency range to be attenuated by resonance. According to the embodiment, the noise reducers 12A and 12B have the closed ends 12Aa and 12Ba and open ends 12Ab and 12Bb, respectively, to serve as a resonator or an acoustic damper capable of selecting the center frequency and frequency band width of compression waves to attenuate.

According to this embodiment, the noise reducers 12A and 12B have cylindrical shapes. The shapes of the noise reducers 12A and 12B are not limited to cylinders. They may have rectangular pipe shapes to provide the same effect as the cylindrical ones if the rectangular pipes have each an equivalent diameter of $D = 2 \cdot (S / \pi)^{1/2}$ equal to the diameter of the cylinder.

Detected results of the noise emission characteristics of exhaust systems each employing the exhaust chamber 10 according to the embodiment of the present invention will be explained.

In the exhaust systems, the exhaust chamber 10 was arranged in the exhaust tube 1 between the premuffler 4 and the rear muffler 5 alternatively at a front location (close to the premuffler 4), a middle location, and a rear location (close to the rear muffler 5). With these three arrangements of the exhaust chamber 10, Fig. 8 shows the dependence of noise levels on pulsator revolution speed and Figs. 9A-9C show frequency characteristics with the pulsator being fixed at a revolution speed of 4,350 rpm.

Figures 8 and 9A-9C show that a greater noise reduction effect is obtainable when the exhaust chamber 10 is arranged close to the rear muffler 5 and upstream from the rear muffler 5 in an exhaust flowing direction. The reason for this is that because the noise reducers 12A and 12B of the exhaust chamber 10 define acoustic boundaries, arranging the exhaust chamber 10 at the front part of the exhaust tube 1 increases the influence of resonance between the exhaust chamber 10 and the rear muffler 5. The frequency analysis results as shown in Figs. 8 and 9 show that the noise contains more high-frequency components of 8kHz or below as the exhaust chamber 10 to the front part of the exhaust tube 1 is arranged closer.

Figure 10 shows relationships between emitted noise levels and pulsator revolution

speeds with and without the exhaust chamber 10, to clarify the effect of the exhaust chamber 10. It is apparent from Fig. 10 that the effect of the exhaust chamber 10 becomes conspicuous as the revolution speed of the pulsator increases thus increasing high-frequency components and that the effect of the exhaust chamber 10 corresponds to 10 dB or more.

Figure 11 shows the effect of the exhaust chamber 10 attached to an exhaust system on the reduction of frequency components in emitted noise. The effect is conspicuous, in particular, in the range of 500 Hz to 3000 Hz. It is understood that the exhaust chamber 10 is applicable to any exhaust system to reduce emitted noise.

The exhaust chamber 10 according to the present invention has a simple structure involving the noise reducers 12A and 12B projected from the outer circumferential face 1a of the exhaust tube 1 by different protrusion heights. Due to this simple structure, the exhaust chamber 10 has layout flexibility and is economical in cost. Exhaust from an engine is passed through the exhaust tube 1 and is guided into the noise reducers 12A and 12B of the exhaust chamber 10, which successively attenuate compression waves of the exhaust having noise generating frequencies of 500 Hz to 3000 Hz through resonance or interference. In this way, the exhaust chamber 10 can effectively reduce the intensity of pulsating waves of exhaust discharged into the rear muffler 5.

Since the exhaust chamber 10 is arranged upstream (closer to the engine) from the rear muffler 5 in the exhaust system, high-frequency noise remaining in the exhaust discharged into the rear muffler 5 can be muffled in the rear muffler 5, and the silenced exhaust is discharged to the outside.

When applied to an exhaust system, the exhaust chamber 10 according to the present invention can reduce frequency levels that cause noise. Accordingly, the exhaust chamber 10 helps standardize the design of the rear muffler 5, to greatly reduce the cost of the exhaust system.

The first embodiment forms the exhaust chamber 10 by protruding the noise reducers 12A and 12B from the exhaust tube 1. The present invention is not limited to the embodiments described above. For example, as shown in Figs. 12A and 12B, the noise reducers 12A and 12B of the exhaust chamber 10 may be filled with noise absorbing material K such as glass wool, rock wool, or urethane (if low temperature is expected) to efficiently absorb the energy of compression waves. To prevent the noise absorbing material K from scattering, a scatter preventive mesh 21 may be provided for an entrance (substantially in the same plane as

an inner wall face of the exhaust tube 1) of each of the noise reducers 12A and 12B. In this case, the noise absorbing material K further improves the noise reducing effect.

Second Embodiment

Figures 13A and 13B show an exhaust chamber according to the second embodiment of the present invention, in which Fig. 13A is a front view showing the exhaust chamber and Fig. 13B is a sectional view taken along a line XIIIB-XIIIB of Fig. 13A.

In Figs. 13A and 13B, the exhaust chamber 30 is basically the same as the exhaust chamber 10 of the first embodiment except that the exhaust chamber 30 has a noise reducer 31 of different shape and the number of noise reducers is different from that of the first embodiment.

The noise reducer 31 of the exhaust chamber 30 has different protrusion heights between front and rear parts thereof along the length (z-axis) of an exhaust tube 1. The protrusion heights are measured in a direction (x-axis direction) intersecting the principal direction (z-axis) of the exhaust tube 1, and distributes from about 30 mm to 150 mm according to the second embodiment. Due to the different protrusion heights, a closed top end face 31a of the noise reducer 31 inclines.

The exhaust chamber 30 is arranged in the exhaust tube 1 close to a rear muffler 5 in an exhaust system. Exhaust generated in an engine is passed through the exhaust tube 1 and is guided into the noise reducer 31 before the rear muffler 5, and the noise reducer 31 successively attenuates, through resonance, frequency levels that are caused by pulsation of the exhaust and may cause noise. Since the top face 31a of the noise reducer 31 is inclined by a predetermined value, the noise reducer 31 with a limited volume can attenuate a wide range of high-frequency levels and reduce a wide range of pulsation levels of the exhaust to be discharged into the rear muffler 5. The exhaust chamber 30 according to this embodiment is an acoustic damper serving as a resonator having the closed end 31a and an open end 31b capable of selecting a frequency band width of compression waves to damp from a wider range. The number of slopes on the top face 31a is not limited to one. Namely, the top face 31a may include a plurality of slopes or curved faces.

According to the second embodiment, the exhaust chamber 30 is formed in the exhaust tube 1 with the noise reducer 31 protruding from the exhaust tube 1 and the top face 31a inclining by a predetermined value. This arrangement does not limit the present invention.

For example, the noise reducer 31 may be filled with noise absorbing material such as glass wool. To prevent the noise absorbing material from scattering, a scatter preventive mesh may be arranged at an entrance (substantially in the same plane as an inner wall face of the exhaust tube 1) of the noise reducer 31. In this case, the noise absorbing material improves the dispersion of compression wave energy and further increases the effect of reducing high-frequency components.

Third Embodiment

Figure 14 is a sectional view showing an exhaust chamber according to the third embodiment of the present invention. The exhaust chamber 40 of Fig. 14 is basically the same as the exhaust chamber 10 of the first embodiment except that the exhaust chamber 40 has noise reducers 41A and 41B of different shapes and different locations from the noise reducers of the first embodiment.

A pair of openings 1b and 1c are formed on an outer circumferential face 1a of an exhaust tube 1 and the noise reducer 41A is arranged to connect the openings 1b and 1c to each other. Another pair of openings 1d and 1e are formed on the outer circumferential face 1a and the noise reducer 41B is arranged to connect the openings 1d and 1e to each other. Namely, the noise reducer 41A has the open ends 1b and 1c open to an inner circumferential face of the exhaust tube 1, and the noise reducer 41B has the open ends 1d and 1e open to the inner circumferential face of the exhaust tube 1.

A distance between the openings 1b and 1c of the noise reducer 41A and a distance between the openings 1d and 1e of the noise reducer 41B may be changed in a predetermined range (about 50 mm to 200 mm in this embodiment) depending on a peak level of emitted noise caused by exhaust. At the same time, the total length of each of the noise reducers 41A and 41B can be changed in a predetermined range (about 150 mm to 300 mm in this embodiment). The noise reducer 41A and a part 41C of the exhaust tube 1 between the openings 1b and 1c form a resonator. A path length L1 of the noise reducer 41A for compression waves, a path length L0 of the exhaust tube part 41C for compression waves, and the difference of path length L1-L0 determine a peak level of emitted noise. The noise reducer 41B is also configured in the same way.

The exhaust chamber 40 of the third embodiment expedites the dispersion of energy of compression waves in a given frequency band through resonance or interference, thereby

attenuating the vibration components of the compression waves. The noise reducer 41A has the two open ends 1b and 1c and the noise reducer 41B has the two open ends 1d and 1e, to form an acoustic damper serving as a resonator capable of selecting the center frequency and frequency band width of compression waves to attenuate.

The cross-sectional area of each of the noise reducers 41A and 41B is an important factor when designing the noise reducers 41A and 41B, as explained in connection with the first embodiment. When determining the locations of the noise reducers 41A and 41B, the openings 1b and 1d to be arranged on the upstream side among the openings 1b, 1c, 1d, and 1e must be distanced at least by 50 mm from each other. Subject to this condition, the noise reducers 41A and 41B may be positioned anywhere in the exhaust tube 1. It is preferable to arrange the noise reducers 41A and 41B in the same plane to make the exhaust chamber 10 compact.

According to the third embodiment, the openings 1b, 1c, 1d, and 1e and the noise reducers 41A and 41B are each circular. This does not limit the present invention. For example, the shapes of the openings 1b, 1c, 1d, and 1e and the noise reducers 41A and 41B may be rectangular to provide the same effect as the circular ones if the equivalent diameter of the rectangular one is equal to the diameter of the circular one.

The exhaust chamber 40 has a simple structure with at least two pairs of openings 1b, 1c, 1d, and 1e being formed on the outer circumferential face 1a of the exhaust tube 1 and being connected to each other through the noise reducers 41A and 41B. The exhaust chamber 40, therefore, has layout flexibility and is economical in cost. In the exhaust system, exhaust from an engine is passed through the exhaust tube 1 and is guided into the noise reducers 41A and 41B of the exhaust chamber 40 before a rear muffler 5. The exhaust chamber 40 causes interference in high-frequency components produced by pulsation of the exhaust. As a result, the exhaust chamber 40 of simple structure attenuates the levels of high-frequency components of the exhaust that cause noise. Namely, the exhaust chamber 40 can effectively reduce a wide range of pulsation levels of the exhaust discharged into the rear muffler 5.

Since the exhaust chamber 40 is arranged upstream (on the engine side) from the rear muffler 5 in the exhaust system, high-frequency noise remaining in the exhaust discharged into the rear muffler 5 can be muffled by the rear muffler 5, and the silenced exhaust can be discharged to the outside.

The exhaust chamber 40 can reduce emitted noise by application to an exhaust system.

Accordingly, the exhaust chamber 40 helps standardize the design of a rear muffler, to greatly reduce the cost of the exhaust system.

According to the third embodiment, the exhaust chamber 40 is constituted by forming two pairs of the openings 1b, 1c, 1d, and 1e on the outer circumferential face 1a of the exhaust tube 1 and by connecting these openings to each other with the noise reducers 41A and 41B. This configuration does not limit the present invention. For example, an exhaust chamber 50 shown in Fig. 15 is possible. In Fig. 15, parts corresponding to those of Fig. 14 are represented with like reference numerals. The exhaust chamber 50 has noise reducers 41A and 41B filled with noise absorbing material K such as glass wool, rock wool, or urethane (if low temperature is expected). To prevent the noise absorbing material K from scattering, a scatter preventive mesh 51 can be arranged at each of the openings 1b, 1c, 1d, and 1e of the noise reducers 41A and 41B. The noise absorbing material K can further improve the emitted noise reducing effect.

The exhaust chambers according to the first to third embodiments of the present invention have been explained. The present invention is not limited to these embodiments. Other various embodiments will be possible without departing from the spirit and scope of the present invention.

According to the embodiments, the exhaust chambers 10, 20, 30, 40, and 50 are each constructed by forming two sheet materials into proper shapes by pressing, abutting the two formed sheet materials against each other, and joining them together by, for example, welding or caulking. This does not limit the present invention. For example, the exhaust chambers may be formed at lower cost by hydroforming.

Fourth Embodiment

Figures 16, 17A, and 17B show an exhaust system according to the fourth embodiment of the present invention, in which Fig. 16 is a general view schematically showing the exhaust system and Figs. 17A and 17B are partly broken front and top sectional views showing a rear muffler incorporating an exhaust chamber according to the fourth embodiment. The structure of the exhaust chamber 60 of this embodiment is the same as the exhaust chamber 10 of the first embodiment, and therefore, the same parts as those of the first embodiment will not be explained in detail.

In Fig. 16, the exhaust chamber 60 according to this embodiment is arranged to also

serve as a front end plate 61 in the rear muffler 55 in the exhaust system. In Figs. 17A and 17B, the exhaust chamber 60 has a first end being open to an insertion tube 63A that is a part of an exhaust tube 1 to guide exhaust into the rear muffler 55. A second end of the exhaust chamber 60 is closed. The exhaust chamber 60 consists of a plurality of noise reducers 62A and 62B having different protrusion heights from the exhaust tube 1, i.e., different distances between the first and second ends of the exhaust chamber 60. The difference between the heights of the noise reducers 62A and 62B is predetermined. The insertion tube 63A serving as the front end plate 61 communicates with the exhaust tube 1 through an opening 55A of the rear muffler 55. The noise reducers 62A and 62B have top faces 62Aa and 62Ba, respectively, corresponding to the second end of the exhaust chamber 60. The top faces 62Aa and 62Ba may substantially be parallel with the exhaust tube 1. In this case, the distances from the exhaust tube 1 to the top faces 62Aa and 62Ba of the noise reducers 62A and 62B, i.e., the projection heights of the noise reducers 62A and 62B differ from each other by a predetermined value.

The insertion tube 63A has a first end that forms substantially a right angle to the exhaust tube 1 and communicates therewith and a second end that forms substantially a right angle to a partition wall 64 in the rear muffler 55 and is extended thereto.

The difference between the projection heights of the noise reducers 62A and 62B and the cross-sectional areas of the noise reducers 62A and 62B are important factors of the fourth embodiment, like the first embodiment.

The insertion tube 63A from which the exhaust chamber 60 protrudes guides exhaust to the downstream side thereof. The exhaust is discharged from the insertion tube 63A into a downstream chamber of the rear muffler 55 partitioned with the partition wall 64 having, for example, a mesh structure. Thereafter, the exhaust is guided into an exhaust tube 63B from which to the atmosphere. At this time, part of the exhaust passes through air holes 63a of the insertion tube 63A, air holes 63b of the exhaust tube 63B, and the partition wall 64. This results in canceling high-frequency noise caused by the exhaust.

The exhaust chamber 60 as the acoustic dumper is arranged at an exhaust upstream side in the rear muffler 55 of the exhaust system. Accordingly, even if the exhaust discharged from the insertion tube 63A contains little high-frequency noise, the noise can be silenced when the exhaust passes through the air holes 63a of the insertion tube 63A, the air holes 63b of the exhaust tube 63B, and the partition wall 64. Thereafter, the noise silenced exhaust is discharged into the atmosphere.

In the exhaust system, the exhaust chamber 60 according to the fourth embodiment can reduce noise-causing frequency levels and help standardize the rear muffler 55. In addition, the exhaust chamber 60 serves as the front end plate 61 of the rear muffler 55, to reduce noise emitted from the rear muffler 55 without increasing the number of parts. This results in greatly reducing the cost of the exhaust system.

According to the fourth embodiment, the exhaust chamber 60 is formed by protruding the noise reducers 62A and 62B from the insertion tube 63A communicating with the exhaust tube 1. This does not limit the present invention. For example, as shown in Fig. 18, the noise reducers 62A and 62B may be filled with noise absorbing material K such as glass wool, rock wool, or urethane (if low temperature is expected). To prevent the noise absorbing material K from scattering, a scatter preventive mesh M may be provided for an opening (substantially in the same plane as an inner wall face of the insertion tube 63A) of each of the noise reducers 62A and 62B. In this case, the noise absorbing material K further improves the noise reducing effect.

First Modification

Figures 19A and 19B show an exhaust chamber 70 according to a first modification of the fourth embodiment of the present invention. The exhaust chamber 70 of Figs. 19A and 19B is basically the same as the exhaust chamber 60 of Figs. 18A and 18B except that the exhaust chamber 70 has a noise reducer 71 of different shape and that the number of protruding noise reducers is different. A resonator structure of the exhaust chamber 70 is the same as that of the exhaust chamber 30 of the second embodiment, and therefore, detailed explanation thereof will be omitted.

According to this modification, the exhaust chamber 70 is formed on an insertion tube 63A communicating with an exhaust tube 1. The noise reducer 71 of the exhaust chamber 70 protrudes from the insertion tube 63A and has a top face 71a inclined by a predetermined quantity. This does not limit the present invention. For example, as shown in Figs. 20A and 20B, the noise reducer 71 may be filled with noise absorbing material K such as glass wool, rock wool, or urethane (if low temperature is expected). To prevent the noise absorbing material K from scattering, a scatter preventive mesh M may be provided for an opening (substantially in the same plane as an inner wall face of the insertion tube 63A) of the noise reducer 71. In this case, the noise absorbing material K further improves the noise reducing effect.

Second Modification

Figure 21 shows an exhaust chamber 80 according to a second modification of the fourth embodiment of the present invention. The exhaust chamber 80 is basically the same as the exhaust chamber 60 of Figs. 17A and 17B except that the second modification employs an insertion tube 63A of different shape from which noise reducers 81A and 81B of the exhaust chamber 80 protrude. The structure of the exhaust chamber 80 is the same as the exhaust chamber 10 of the first embodiment, and therefore, the detailed explanation thereof will be omitted.

The insertion tube 63A from which the noise reducers 81A and 81B of the exhaust chamber 80 protrude has a first end substantially linearly communicating with an exhaust tube 1 and a second end substantially linearly extending to a partition wall 64 in a rear muffler 55.

The exhaust chamber 80 is formed at an exhaust upstream side in the rear muffler 55 of the exhaust system. Exhaust generated in an engine or a compressor is passed through the exhaust tube 1 and guided into the rear muffler 55. At this time, the exhaust is guided into the noise reducers 81A and 81B of the exhaust chamber 80, to successively attenuate, through resonance, a frequency range of about 500 Hz to 3000 Hz of the exhaust that may cause noise. This effectively reduces pulsation levels of the noise discharged into an exhaust tube 63B.

According to this modification, the exhaust chamber 80 is formed on the insertion tube 63A communicating with the exhaust tube 1 with the noise reducers 81A and 81B of the exhaust chamber 80 protruding from the insertion tube 63A. This does not limit the present invention. For example, as shown in Fig. 22, the noise reducers 81A and 81B may be filled with noise absorbing material K such as glass wool, rock wool, or urethane (if low temperature is expected). To prevent the noise absorbing material K from scattering, a scatter preventive mesh M may be provided for an opening (substantially in the same plane as an inner wall face of the insertion tube 63A) of each of the noise reducers 81A and 81B. In this case, the noise absorbing material K further improves the noise reducing effect.

Third Modification

Figure 23 shows an exhaust chamber 90 according to a third modification of the fourth embodiment of the present invention. The exhaust chamber 90 is basically the same as the exhaust chamber 70 of Fig. 22 except that the exhaust chamber 90 has noise reducers 91A and 91B of shapes different from those of Fig. 22. A resonator structure of the exhaust chamber 90 is the same as that of the exhaust chamber 40 of the third embodiment, and therefore, the

explanation thereof will not be repeated.

The exhaust chamber 90 is formed by forming two pairs of openings 92a, 92b, 92c, and 92d in an insertion tube 63A and connecting the openings 92a and 92b to each other through the noise reducer 91A, and the openings 92c and 92d to each other through the noise reducer 91B.

A distance between the openings 92a and 92b of the noise reducer 91A and a distance between the openings 92c and 92d of the noise reducer 91B are changed in a predetermined range (about 50 mm to 200 mm according to this modification) depending on a peak level of emitted noise caused by exhaust. At the same time, the total length of each of the noise reducers 91A and 91B is changed in a predetermined range (about 150 mm to 300 mm according to this modification).

The cross-sectional area of each of the noise reducers 91A and 91B is an important factor when designing the noise reducers 91A and 91B. When determining the locations of the noise reducers 91A and 91B, the openings 92a and 92c to be arranged on the upstream side among the openings 92a, 92b, 92c, and 92d must be distanced at least by 50 mm from each other. Subject to this condition, the noise reducers 91A and 91B may be positioned anywhere on the insertion tube 63A.

According to this modification, the openings 92a to 92d and the noise reducers 91A and 91B are each circular. This does not limit the present invention. For example, the shapes of the openings 92a to 92d and the noise reducers 91A and 91B may be rectangular to provide the same effect as the circular ones if the equivalent diameter of the rectangular one is equal to the diameter of the circular one.

The exhaust chamber 90 has a simple structure with the two pairs of the openings 92a, 92b, 92c, and 92d being formed in the insertion tube 63A and being connected to each other through the noise reducers 91A and 91B. The exhaust chamber 90, therefore, has layout flexibility and is economical in cost.

According to the exhaust system, exhaust generated in an engine or a compressor is passed through an exhaust tube 1 and guided into a rear muffler 55. At this time, the exhaust is guided into the noise reducers 91A and 91B of the exhaust chamber 90, to cause interference in high-frequency components caused by pulsation of the exhaust. Namely, this simple structure can attenuate the levels of the high-frequency components of the exhaust that may cause noise and can effectively reduce a wide range of pulsation levels of the exhaust discharged into an

exhaust tube 63B.

The exhaust chamber 90 is arranged upstream from the rear muffler 55 in the exhaust system. Accordingly, even if the exhaust discharged from the insertion tube 63A contains little high-frequency noise, the noise can be silenced when the exhaust passes through air holes 63a of the insertion tube 63A, air holes 63b of the exhaust tube 63B, and a partition wall 64. Thereafter, the silenced exhaust is discharged into the atmosphere.

In the exhaust system, the exhaust chamber 90 can reduce emitted noise, and therefore, can help standardize the rear muffler 55 and greatly reduce the cost of the exhaust system.

According to this modification, the exhaust chamber 90 is constituted by forming the openings 92a, 92b, 92c, and 92d in the insertion tube 63A and connecting the openings 92a and 92b to each other through the noise reducer 91A and the openings 92c and 92d to each other through the noise reducer 91B. This does not limit the present invention. As shown in Fig. 24, the noise reducers 91A and 91B may be filled with noise absorbing material K such as glass wool, rock wool, or urethane (if low temperature is expected). To prevent the noise absorbing material K from scattering, a scatter preventive mesh M may be provided for each of the openings 92a, 92b, 92c, and 92d. In this case, the noise absorbing material K further improves the noise reducing effect.

Although the present invention has been explained with reference to exhaust chambers based on embodiments of the present invention, the present invention is not limited to these embodiments. Without departing from the spirit and scope of the present invention, various other embodiments are possible, and such embodiments are considered to fall in the scope of the present invention.

For example, the exhaust chambers 60, 70, 80, and 90 according to the fourth embodiment and the modifications thereof are each formed by forming two sheet materials into proper shapes by pressing, abutting the two formed sheet materials against each other, and joining them together by, for example, welding or caulking. This does not limit the present invention. For example, the exhaust chambers may be formed at lower costs by hydroforming.